PDP-1 COMPUTER
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PDP-6

TIME-SHARED OPERATION OF THE ELECTRICAL ENGINEERING PDP-1 COMPUTER

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This memorandum describes the time-sharing system for the Electrical Engineering Department PDP-1 computer and the limitations that the system imposes on programs written for the PDP-1. Every effort has been made to make as many features of the basic machine available to users as possible, although some sacrifices must be made to make the computing capacity of the machine available simultaneously to several users.

1. Components of the System

As shown in Figure 1, the system consists of the PDP-1 central processor, a magnetic drum, two consoles, one paper tape reader, one paper tape punch, one CRT display. Provision for external interruption of and data transfer to or from a time-shared program is provided. Up to 5 additional consoles and a second reader, punch and display may be added to the system eventually.

2. Mode of Operation

The time sharing of a small memory computer by several programs is accomplished by running each program for one quantum of computation while the other programs occupy auxiliary storage. In the PDP-1 system this storage takes the form of a magnetic drum. The drum will store 22 fields of information, each field containing 4,096 words. The drum control is designed to simultaneously transfer data to and from the PDP core memory, at a rate of 4,096 words in 33 milliseconds. The detailed characteristics of the drum and the instructions of its control are described elsewhere.

One drum field is assigned to each operating user for saving his program while programs of the other users are being run. Some of the remaining fields will be reserved for utility and conversion programs, and some will be available to users in a manner indicated later.

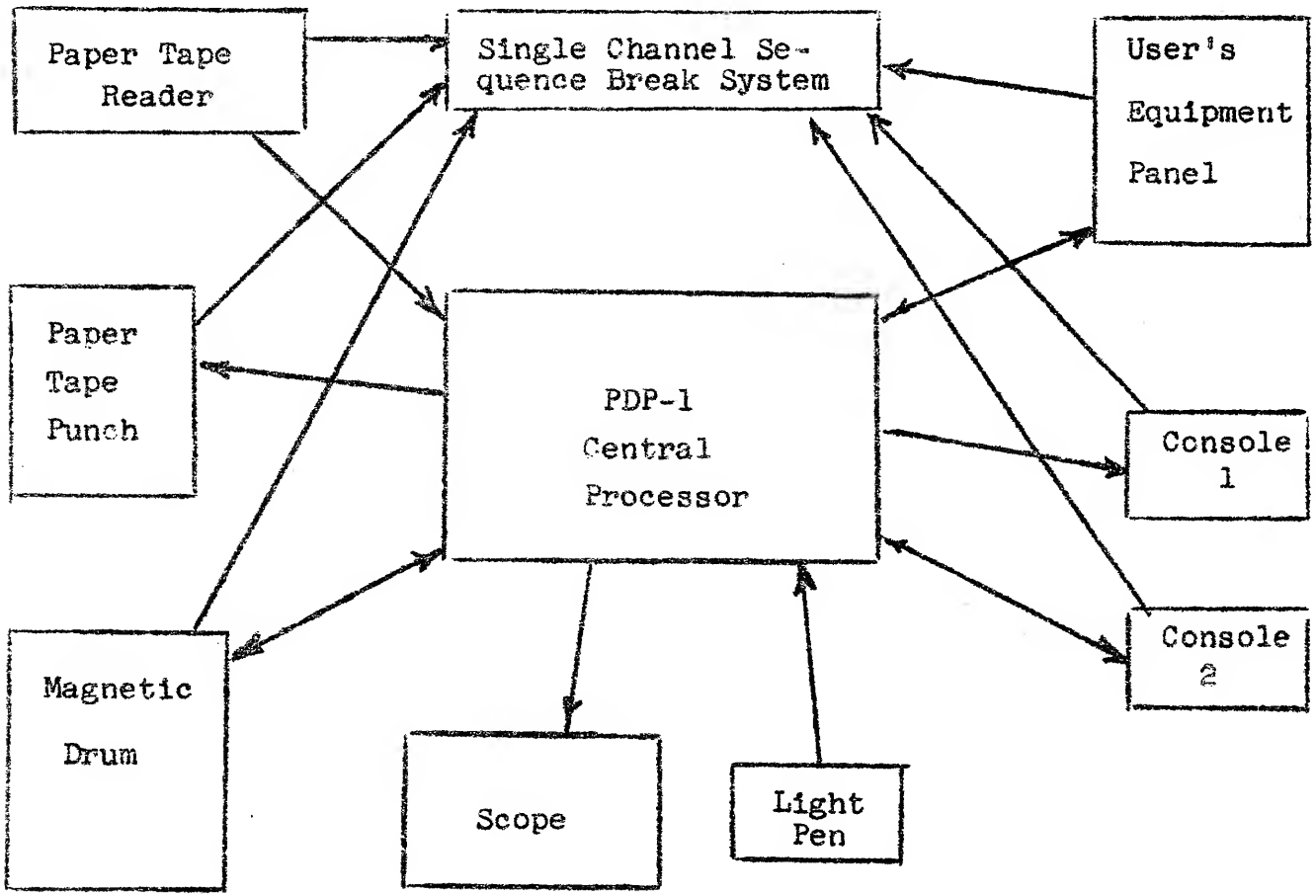

Figure 1 -- Components of the PDP-1 time sharing computer system

3. Executive Routine

In order to control the exchange of programs between core and drum, and to provide for the assignment and effective use of the various in/out devices, a portion of core memory is reserved for an executive program as shown in Figure 2. The registers occupied by the executive program are protected and hence unavailable to users' programs. The executive routine requires approximately 512 registers, plus a relatively short section which is different for each user according to his needs for in/out equipment and other features of the system. This portion of the executive routine is called the users' protected block. It is transferred to and from the drum along with the users' programs.

4. Administrative Program

The time-sharing system must provide for assignment of in/out facilities such as paper tape reader and punch, the CRT display, fields of storage on the drum, etc. to individual users according to demand.

Requests for assignment of in/out facilities are handled by an administrative program which occupies one section of the drum, and time-shares core memory with users' programs when its services are needed. The administrative program also provides for program read-in, and places utility and conversion programs at the users' service upon request.

5. Trapping

During the course of operation of a user's program a number of events can occur which cause control to be transferred to the executive routine through trapping:

(A) Time out interrupt--every nine milliseconds a time out will occur to allow the executive routine to process characters being punched, printed on consoles, or typed in, as described in a later section. This trap also allows the executive routine to swap core and drum so that another user's program may be run.

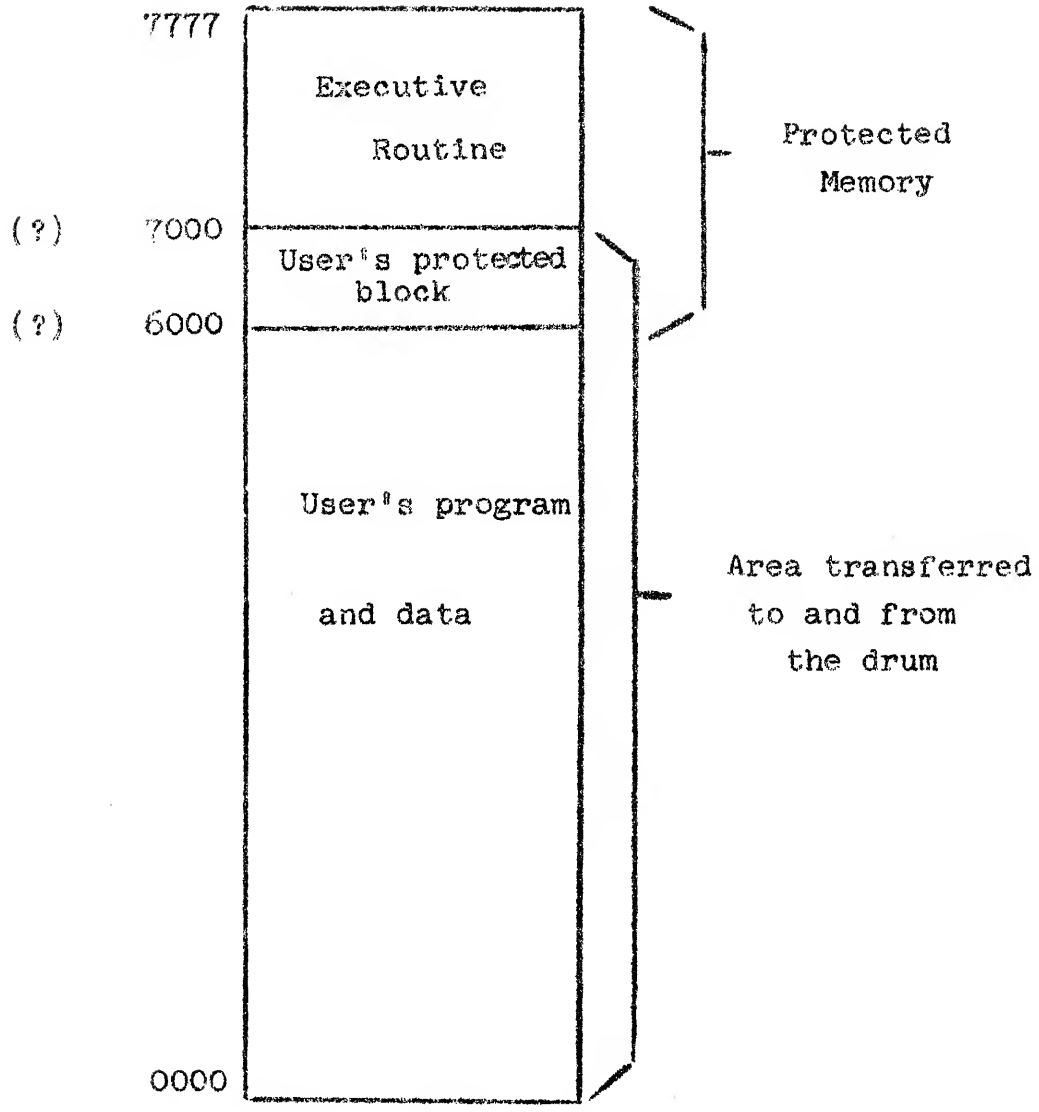

Figure 2 -- Core memory allocation

(B) Instruction traps--various instructions which call for action by the executive routine will result in trapping as follows:

1. Illegal instructions--control is passed to the administrative program, or to the user's debugging program, if one is assigned, which will print a diagnostic comment.

   a. incorrect operation code
   b. hlt
   c. an attempt to address protected memory.
   d. iot xx77 - instructions legal only for the executive routine.
   e. rpa and rpb instructionswhen the tape reader is not assigned.
   f. dba, dia, dcc and dra when drum fields are not assigned.
   g. the lat instruction when not assigned.

2. Certain in/out transfer instructions which require checking and processing by the executive routine.

   a. tyi, tyo, ppa, ppb -- Characters transferred between PDP and the consoles or punch are buffered by the executive routine.
   b. dba, dia, dcc, dra -- These instructions are checked, modified and executed by the executive routine when assigned to a user. (See section 11.)

3. Special Instructions

   a. bpt = iot 3077 -- Implanted by debugging routines as a program break point. Control is passed to the user's debugging program.

   b. arq = iot 3177 -- This instruction is a request to the administrative program from a user's program for assignment of an in/out facility. The specific facility is determined by the contents of IO or AC. Control is passed to the administrative routine.

6. Consoles

Each console of the time sharing system consists of a typewriter and a small panel of switches and indicators as shown in Figure 3. The typewriter appears to the user's program as the standard DEC in-out typewriter, i.e., printing is performed by tyo commands and manually typed characters are accepted by tyi commands. The console is normally in type status and is placed in print status when type out is required.

tyo -- places a character from the IO register in the executive routine buffer to be printed when the typewriter is ready. If his buffer is full, the user's quantum is ended. The console is placed in print status by the executive routine and characters are printed from the buffer until it is empty. Then the console returns to type status. Time: about 500 microseconds.

tyi -- Places a character in the IO register from the executive routine buffer. If the buffer is empty, this user's quantum ends. The executive routine accepts manually typed characters and enters them in the buffer while the console is in type status. If the buffer becomes filled, the type in light will go out (see below) and further characters typed will be lost. Time: about 500 microseconds.

The use of the tyo instruction is exactly as in normal PDP programming. In the case of tyi, program flag one should not be used as this will result in inefficient operation of the user's program and the time sharing system. To read the next character into the IO register which is available from the executive routine simply execute the instruction tyi.

Programs written for operating the typewriter in sequence break mode may also be run. (See section 14.)

7. Switches and Indicators

(a) Console switch -- Turning the console switch on places the administrative routine at the service of the user, so that he may enter requests for services and equipment via his typewriter. Turning the console switch off momentarily and then back on will again place the administrative routine at the service of the user without loss

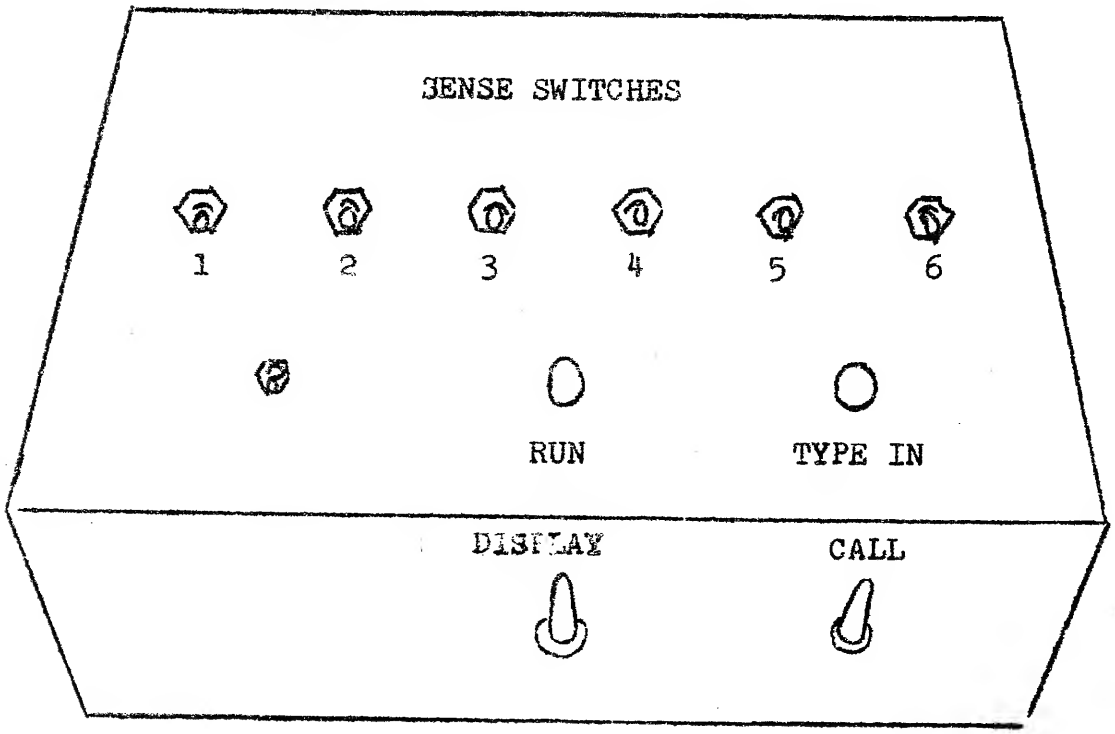

Figure 3 -- Console switch and indication panel

of equipment assignment. If the console switch is left off for more than about 15 seconds, the administrative routine will assume the user has finished, and make assigned equipment available to other users.

(b) Console button -- When the console button is pressed, control is transferred to a point in the user's program which he may specify by a request to the administrative routine. Normally, this provides the means of returning control to a debugging routine when a program under test fails.

(c) Console run light -- This light is on during quanta assigned to this user.

(d) Type in light -- This light is on when the console is in type status and the executive routine buffer is not full.

(e) Display lever -- Depressing this lever activates display instructions in this user's program and grants long quanta so that the performance of a display program may be observed. (The display lever is also available for other similar purposes such as permitting an uninterrupted data transfer to or from external equipment.)

(g) Sense switches -- These switches substitute for the sense switches on the PDP indication panel while this user's program is running.

8. Paper Tape Punch

Use of the paper tape punch must be requested by an appropriate command to the administrative routine. Once the punch has been assigned, information may be transferred by a sequence of ppa and ppb instructions:

ppa, ppb: Transfer one character from IO to the executive routine punch buffer for transfer to the punch when it is ready. If the buffer is full, the user's quantum ends. Time: about 500 microseconds.

For programming of the punch in sequence break mode, see section 14.

9. Paper Tape Reader

Use of the paper tape reader must be requested by an appropriate command to the administrative routine. Once the reader is assigned, information may be read by rpa or rpb instructions. These instructions operate the tape reader directly, as in normal PDP programming. A program using the tape reader will be granted long quanta so that a reasonable amount of data may be read in for each time the user's program is placed in core memory.

If information becomes assembled in the reader buffer while the user's program is not running, the completion pulse is delayed until the user's program is returned to core memory and placed in operation.

The instruction ioh = iot i may be used following reader commands without wait, rpa-i or rpb-i, to hang up a program until a reader completion pulse occurs.

The reader may also be operated in sequence break mode.

10. CRT Display and Light Pen

The display instruction will operate as in the standard PDP. However, the point called for will only be displayed if a CRT is assigned to the user by request to the administrative program and the display instruction is enabled by the executive routine. When a user depresses his display lever, he will be granted several long quanta during which the display is enabled.

If an interrupt occurs during the in-out halt of a display instruction, the current point will be displayed a second time upon dismissal. This can be avoided by using the sequence

```
dpy-i        ioh
```

instead of

```
dpy
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The light pen will operate as in the standard PDP-1.

11. Drum

By request to the administrative routine users will be assigned contiguous groups of drum fields not already occupied. Field references in users programs must start with field zero. Field numbers employed in a user's program are translated and checked for validity by the executive routine. The drum instructions operate as follows:

dra -- the address read will be about 50 words in advance of the actual position of the drum to allow for processing by the executive routine. Time: about 100 microseconds.

dba -- The address given will be advanced by approximately 50 words to allow for processing by the executive routine. Occurrence of the sequence break will interrupt the user's program and turn on the drum status bit as discussed in section 14.
The status bit is cleared by the next dcc command.
Time: about 200 microseconds.

dia -- The field number is checked and translated by the executive routine. Time: about 150 microseconds.

dcc -- The field number is translated by the executive routine. Time: about 300 microseconds plus access and transfer time.

12. In-Out Halt

In programs run on the time sharing system, an in-out halt will occur for rpa, rpb and dpy instructions as explained above. The in-out halt instruction ioh will cause an in-out halt if a display or tape reader operation is not complete. The in-out halt will last until both devices are free, i.e., they have completed any operation in progress. With these exceptions, the in-out halt bit of all iot instructions will have no effect on program operation. Also bit 6 of iot instructions, the "need-a-completion" bit is irrelevant to program operation.

13. Connection of Users' External Equipment

An arrangement is provided so that time shared programs may communicate with the users' external equipment. Figure 4 shows the facilities provided, and the connections between PDP and the users' equipment.

(1) IO register outputs -- A set of DEC type 1685 buffer amplifiers provides ground levels for ones in the IO register for all transfer of data to users' equipment.

(2) Input mixer -- An 8 leg mixer of DEC type 4129 capacitor diode gates allows for inputs of ones to the IO register.

(3) Clear IO inputs -- An OR circuit is provided so that iot pulses may be used to clear the IO register in preparation for transferring information to the PDP.

(4) External equipment assignment levels -- Each user who is connecting external apparatus to the PDP will be allocated one of the seven external equipment assignment levels. The administrative routine will turn on this level whenever the corresponding user's program is actually in operation.

(5) IOT command pulses -- Command pulses for iot xx10 through iot xx17 are available at TP_{7-4} and TP_{10-4} for external use. These pulses must be gated by the appropriate assignment level to prevent other users from activating your equipment. No in/out stop is permitted: The sequence break system must be used to signal when equipment is ready to transmit or receive data.

(6) Program flags -- A distinct pair of program flag flip flops is provided for each of the seven assignment levels. These substitute for PDP flags 5 and 6 whenever the corresponding assignment level is on. The assigned pair may be examined or set by the user's equipment at any time.

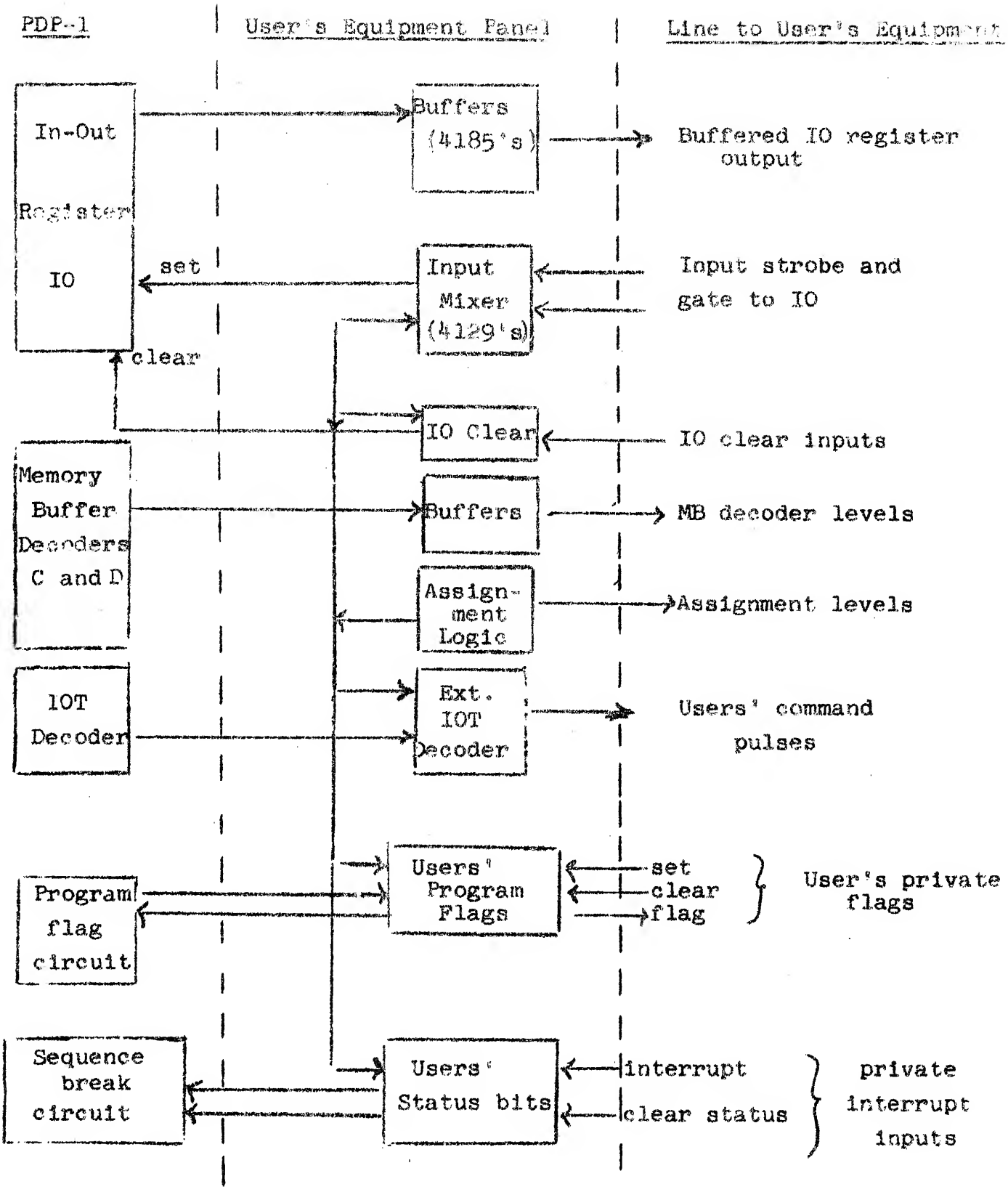

Figure 4 -- Users' External Equipment Panel

(7) Memory buffer decoders -- Sixteen outputs from the MB decoders for bit 6-8 and bits 9-11 are available from bus drivers for further decoding of user's iot's.

(8) Sequence break system inputs and status flip flops--A sequence break input and status flip flop is associated with each of the seven assignment levels. An interrupt pulse will cause a sequence break in the user's program if it is in operation or when it is next placed in operation. The status bit is set by the interrupt pulse, and will normally be cleared by an iot pulse.

14. Sequence Break System

The single channel sequence break will be available to all users of the time sharing system. Operation of the standard sequence break system is described elsewhere and only matters pertaining to time shared use of it will be discussed here.

The following instructions will operate normally when executed in a user's program:

csb	-	clear sequence break system
esm	-	enter sequence break mode
lsm	-	leave sequence break mode
isb	-	initiate sequence break

Table 1 lists the events which will interrupt a user's program through the sequence break system together with the conditions which control the associated status bits as read by the cks instruction. All interrupts to a user's program will be delayed until his program is granted a quantum, placed in operation, and the machine is in sequence break mode. When a user's quantum ends, the contents of the break waiting, break started, and sequence break mode flip flops are preserved together with the status of the AC, IO, PC, and program flags, and are restored before the program is placed in operation for its next quantum.

15. Active and Inactive Programs

While a user's program is active, it will be placed in the PDP core memory and granted a quantum of computation each time its

TABLE 1

Device	Event Causing Interrupt	IO bit for sks	Status Bit Control
Light Pen	None	0	Turned on when pen sees displayed point. Turned off by next dpy command.
Paper Tape Reader	Information becomes available in the reader buffer.		Turned on by interrupt. Turned off by rpa or rpb command.
Paper Tape Punch	The punch is assigned and space in the executive routine punch buffer becomes available for another character, or a ppa or ppb trap occurs and the buffer does not just become full.	2	Status bit on means executive routine can accept a character via a ppa or ppb trap.
Console	The console is not in print status and a typed in character enters the previously empty executive routine console buffer, or a tyi trap occurs and the buffer does not just become empty.	3	Status bit on means executive routine can supply a character via a tyi trap.
	The console is in print status and space in the executive routine console buffer becomes available for another character, or a tyo trap occurs and the buffer does not just become full.	4	Status bit on means executive routine can accept a character via a tyo trap.
Drum	A drum break return occurs.	5	Turned on by interrupt. Turned off by next dcc command.
External Equipment	An interrupt signal is received from external equipment for which the assignment level is on.	6	Turned on by interrupt. Turned off by an assigned iot.

turn comes up. When a user's program is inactive it does not receive quanta and remains on the drum.

An active program will become inactive in any of the following events:

1. The user's program has reached a tyi instruction and no characters are available from this user's console.
2. The user's program reaches a ppa ppb, or tyo instruction and the executive routine's buffer is full.
3. A trap occurs which calls for action by the administrative program. Examples are arg instructions and illegal instructions or halts in the absence of an assigned debugging routine.

An inactive program becomes active under the following conditions in correspondence with the above:

1. A user types a character to his program which is waiting for input.
2. The punch or console printer receives a character from the executive routine buffer, making space for more output from a program hung on a ppa, ppb or tyo.
3. Program operation is begun by request to the administrative routine.
4. The user's program is placed in operation by pressing the console button.

Note that changing a console sense switch will not activate an inactive program.

16. Limitations

Normal PDP-1 programs should operate successfully in this time sharing system provided the following requirements are satisfied:

(a) The necessary in-out devices are available and have been assigned by the administrative routine.

(b) No core memory registers are required beyond a boundary which is approximately location 6600_8, but depends on the particular in-out features assigned.

(c) Only the instructions rpa = iot i 1, rpb = iot i 2 and ioh = iot i are used to halt the computer for paper tape reader operation.

(d) Only the instructions dpy = iot i 7 and ioh = iot i are used to halt the computer for display.

(e) Interruptions by the executive routine every nine milliseconds for buffering characters to or from consoles and the paper tape punch can be tolerated.

(f) Execution of the program in quanta of computation having a duration of a few 30-millisecond intervals can be tolerated.

(g) The program coding does not depend on the relative speeds of the typewriter, punch and tape reader for correct operation. (tyi, tyo, ppa and ppb commands will appear to a time shared program as completing in a much shorter time than normal, e.g. 500 microseconds.)

(h) The timing of data transfer to and from external equipment is done through the sequence break system rather than by the use of in-out wait.